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Reliability and Validity of Ratings of Perceived Exertion in Persons with Multiple Sclerosis

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Abstract

Objective: To test the reliability and validity of using the Borg rating of perceived exertion (RPE) scale (ratings 6–20) in persons with multiple sclerosis (PwMS).

Design: Nonrandomized repeated measures.

Setting: Research laboratory.

Participants: Volunteer sample (N=27) comprised of 16 PwMS (10 women) and 11 age-matched persons without multiple sclerosis (MS) (6 women). Clinical measures included symptomatic fatigue, depression, and MS functional capacity.

Interventions: A submaximal cycling test was performed to estimate maximal capacity. Participants then pedaled for 2 minutes at 50% and 60% of predicted maximal oxygen consumption per unit time ($\dot{V}O_2$), and physiological measures and RPE were obtained (week 1: response protocol). One week later, participants replicated the prescribed $\dot{V}O_2$ using the RPE range from week 1 (week 2: reproduction protocol). $\dot{V}O_2$, heart rate, and respiratory quotient were measured continuously; RPE and workload were measured every minute; and blood lactate and mean arterial pressure were measured after exercise.

Main Outcome Measures: RPE, workload, $\dot{V}O_2$, and heart rate from week 1 to week 2.

Results: PwMS had greater fatigue ($P<.01$) and disability ($P<.001$). Baseline measures were similar between groups and weeks. During exercise, RPE, workload, ($\dot{V}O_2$, and heart rate were similar between groups. Both groups had an intraclass correlation coefficient >.86 for RPE, workload, and $\dot{V}O_2$. The intraclass correlation coefficient was comparatively lower for heart rate for both groups (MS group: .72, non-MS group: .83). RPE was highly correlated with $\dot{V}O_2$ (r=.691, $P<.001$) and workload (r=.700, $P<.001$) for the MS group.

Conclusions: Results suggest that RPE can be reliably reproduced, is valid, and may be used in exercise prescription in mildly to moderately impaired PwMS during cycling exercise.

Keywords: Exercise; Multiple sclerosis; Physical exertion; Rehabilitation

List of abbreviations

- MAP, mean arterial pressure;
- MS, multiple sclerosis;
- MSFC, Multiple Sclerosis Functional Composite;
- PwMS, persons with multiple sclerosis;
- RPE, rating of perceived exertion;
- RQ, respiratory quotient;
- $\dot{V}O_2$, oxygen consumption per unit time

Multiple sclerosis (MS) is an autoimmune disease of the central nervous system which often causes sensory, motor, and autonomic impairment and leads to fatigue, weakness, and decreased physical

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activity.[1, 2 and 3] Exercise for persons with multiple sclerosis (PwMS) was once contraindicated.[4 and 5] Now, evidence supports the use of exercise in PwMS to improve muscle strength,[6, 7 and 8] cardiorespiratory function,[9 and 10] quality of life,[8, 9, 11 and 12] depression,[9, 12 and 13] and fatigue.[9, 11 and 14] Therefore, it is important to develop safe and effective exercise prescriptions and recommendations for PwMS.

Exercise intensity is a key component of exercise prescription[15] and often is prescribed with a training heart rate range. In many fitness settings, a submaximal aerobic test, if any at all, is used to determine a training heart rate range.[16] Submaximal tests rely on an approximation of maximal heart rate, but alterations in cardiovascular autonomic control in some PwMS may lead to error in heart rate approximations.[17, 18, 19 and 20] This may limit the use of heart rate as an indicator of exercise intensity in some PwMS. In addition, heart rate can be altered by factors including exercise mode, posture, temperature, drugs, and anxiety.[21] Many of these factors can be altered in PwMS, which could limit the use of heart rate for exercise prescription in PwMS.

Ratings of perceived exertion (RPEs) have been recommended to monitor exercise intensity in PwMS.[1, 22 and 23] The RPE is mediated by physiological and psychological factors, performance settings, and exertional symptoms.[24] The RPE has been used successfully in many populations[24] and is endorsed for monitoring exercise intensity.[15] Because the RPE is mediated by aspects of exercise in addition to heart rate,[24] it may overcome potential issues with using heart rate for exercise prescription in PwMS or represent an alternative or complementary approach.

Systematic (validity) and random error (reliability) of using the RPE in PwMS may be affected by some of the same factors that might make heart rate unsuitable for exercise prescription. Increased central neural drive,[25 and 26] symptomatic fatigue,[4 and 27] depression,[28] and impaired sensory feedback[29] or integration[30] in PwMS may affect the validity of using the RPE in this population. In addition, greater variability exists in PwMS compared with people without MS for depression,[31] fatigue,[27] information processing,[32] and other factors that could affect the RPE. This greater variability may affect the reliability of the RPE in PwMS.

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Nevertheless, the RPE can be similar in PwMS and people without MS during incremental dynamic exercise to task failure[33] and during submaximal isometric exercise.[34] These earlier studies provide initial validation of the RPE in PwMS. However, little is known about the validity of the RPE during submaximal dynamic exercise, which is typically prescribed for health and fitness. Importantly, it also is not known if the RPE in PwMS is reproducible, which is necessary for validity. If the physiological exercise-related processes associated with the RPE are shown to be reliable and valid in PwMS during submaximal aerobic exercise, then the RPE could be a valuable tool for exercise prescription and monitoring.

Therefore, the purpose of this study was to test the reliability and validity of the Borg RPE scale (ratings 6–20) during submaximal aerobic exercise at a given exercise intensity in PwMS. To achieve some degree of ecologic validity, we determined this exercise intensity using standard techniques and estimated relative intensities that might be used in a fitness setting.

Methods

Participants were tested over 2 visits separated by 6 to 10 days. During the first visit, participants underwent a submaximal exercise test, performed cycling at 50% and 60% of their predicted maximal effort (response protocol), and practiced reproducing the associated RPE (production protocol). During the second visit, participants reproduced the effort from week 1 by matching the same RPE range (reproduction protocol). Testing was performed at 50% to 60% of maximal effort to provide flexibility in the exertion level but maintain the ability to compare responses between weeks. Exercise was performed on an electrically braked cycle ergometer (VIAsprint 150P[a]) at 60±3 revolutions per minute. Questionnaires and baseline physiological measurements were collected prior to exercise each week.

Participants

Participants were initially recruited through advertisements from the Wisconsin chapter of the National Multiple Sclerosis Society. We

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also recruited participants who matched our inclusion criteria from a pool of individuals from unrelated studies. All participants were nonsmokers; had no other major neurologic, metabolic, or cardiovascular diseases; did not use cardiovascular drugs (eg, beta-blockers); and were not in a concurrent clinical drug trial. Control participants were recruited to have a similar mean age and sex composition. All participants provided written informed consent, approved by the Marquette University Institutional Review Board. Sample size was determined to achieve precise estimates of reliability (confidence interval width, 0.2), with an intraclass correlation coefficient of 0.9.[35]

Questionnaires

Prior to exercise testing each week, participants completed questionnaires to assess symptomatic fatigue and depressive symptoms. Symptomatic fatigue was measured with the Modified Fatigue Impact Scale,[36, 37 and 38] and depressive symptoms were measured with the Center for Epidemiologic Studies–Depression Scale.[39 and 40] Participants also reported recent caffeine consumption, hours of sleep the prior night, and recent physical activity. PwMS reported the last date of any disease-modifying therapy. For the second visit, participants were instructed to replicate their levels of caffeine consumption, sleep, and physical activity and maintain a similar therapy regimen. No participants showed noticeable deviations in these measures from week 1 to week 2.

Disability

All participants completed the Multiple Sclerosis Functional Composite (MSFC), a measure of global function consisting of the timed 25-foot walk, 9-hole peg test, and Paced Auditory Serial Addition Task.[41 and 42] Scores from each component were presented individually and were transformed into a *z* score based on a representative database of PwMS. [43]

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Baseline measures

Prior to exercise, baseline measures were obtained with participants seated on the cycle ergometer and included the following: oxygen consumption per unit time ($\dot{V}O_2$) and respiratory quotient (RQ) obtained continuously with open circuit spirometry (Vmax Encore[a]) and calibrated prior to each experimental session; heart rate measured from a heart rate monitor (Polar T31[b]); blood lactate obtained with a finger prick (Lactate Pro[c]); and brachial artery pressure measured by manual sphygmomanometry. Blood pressure is presented as mean arterial pressure (MAP) (diastolic pressure + [1/3 × pulse pressure]). Participants were oriented to and taught how to use the Borg RPE scale (ratings 6–20) as previously described.[24] Orientation included verbal and mental anchoring to the range of exertion on the scale.[24]

Submaximal test

Participants underwent a submaximal Young Men's Christian Association test after performing a 3-minute warm-up at 25W.[44] Maximal $\dot{V}O_2$ was predicted by linear extrapolation of $\dot{V}O_2$ and heart rate to age-predicted maximal heart rate.[15] Intensity levels for exercise testing were determined as a percentage of predicted maximal $\dot{V}O_2$ levels. $\dot{V}O_2$ and heart rate were measured continuously, RPE and workload were measured every minute, and blood pressure was obtained at the end of each stage. Each submaximal test lasted approximately 10 minutes.

Response protocol

The RPE range associated with a range of exercise intensities was determined. Participants rested after the submaximal test until heart rate and MAP returned to baseline levels and then exercised at 50% and 60% of their predicted maximal $\dot{V}O_2$. Two minutes of cycling was performed at each intensity level with no warm-up period. Workloads were set by the investigators, and participants were blinded to this workload. Participants provided RPEs twice for each workload and were instructed to internalize the sensations associated with this RPE range. $\dot{V}O_2$, heart rate, and RQ were continuously measured, and the RPE and workload were recorded every minute. Blood pressure was obtained during the last minute of exercise, and lactate was measured within 1 minute of the termination of exercise.

Production protocol

Next, participants practiced reproducing the effort level from the response protocol to acquaint them with the procedure for the second visit. Participants rested until heart rate and MAP recovered to baseline and then pedaled for 4 minutes within the RPE range they experienced during the response protocol.[21] Blinding was performed, and initial workload was randomly chosen to be 5 to 15W higher or lower than the workload range from the response protocol. Participants were instructed to adjust the resistance to maintain an effort that was within the target RPE range and were encouraged to maintain the desired effort. RPE, $\dot{V}O_2$, heart rate, RQ, lactate, and blood pressure were all collected as during the response protocol.

Reproduction protocol

Then 6 to 10 days later, participants reproduced the effort level from week 1. After a 3-minute warmup at approximately 25W, participants pedaled for 4 minutes and reproduced the RPE range associated with their training range (50%–60% of the estimated maximal $\dot{V}O_2$) from the first visit. Blinding was again performed. Participants were instructed to adjust the resistance to achieve this RPE range. RPE, workload, $\dot{V}O_2$, heart rate, RQ, lactate, and blood pressure were measured in the same manner as during week 1.

Analysis

Repeated-measures analysis of variance was used to compare physiological measures obtained during exercise, resting physiological variables, and questionnaire data from week 1 (response protocol) with week 2 (reproduction protocol) for PwMS and the non-MS group. Intraclass correlation coefficients model 2,1 were obtained to assess the reliability of the RPEs and other physiological measures across weeks.[45] For the response and reproduction protocol, Pearson correlations were performed between the RPE and measured physiological variables as an indication of convergent validity. These

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correlations were then transformed to Fisher *z* scale, averaged, and inverse transformed (average estimate). Student *t* tests were used to compare subject characteristics, MSFC scores, and predicted maximal values between the MS and non-MS groups. Data were analyzed using SPSS Statistics 22.0. [d] Significance was accepted at $P \leq .05$.

Results

Participant characteristics

Sixteen participants with MS (10 women; Expanded Disability Status Scale score median, 1.75; range, 1–5) were compared with 11 participants without MS (6 women) (table 1). Disease courses for the MS group were relapsing-remitting (n=9), progressive (n=5), and unknown (n=2). The MS and non-MS groups were similar in age, height, and mass. The MSFC *z* score was lower in the MS group compared with the non-MS group. Correspondingly, the timed 25-foot walk and 9-hole peg test were slower, and the Paced Auditory Serial Addition Test score was lower in the MS group.

Table 1. Subject characteristics

Variables	MS Group	Non-MS Group	95% CI	*P*
Years since diagnosis	5.5 (1–20)			
Age (y)	45.7±4.9	42.9±7.5	−2.1 to 7.7	.254
Mass (kg)	72.9±18.3	74.6±14.4	−15.3 to 12.0	.804
Height (m)	1.69±0.12	1.73±0.11	−0.13 to 0.06	.451
MSFC *z* score	0.27±0.53	1.01±0.26	−1.1 to −0.39	<.001*
Timed 25-foot walk (s)	4.62±1.77	3.38±0.65	0.08 to 2.40	.037*
9-hole peg test (s)	21.4±4.3	17.0±2.0	1.5 to 7.3	.004*
PASAT	43.9±15.2	56.1±2.9	−20.4 to −3.9	.006*

NOTE. Values are mean ± SD, mean (range), or as otherwise indicated.
Abbreviations: CI, confidence interval; PASAT, Paced Auditory Serial Addition Test.
*$P<.05$.

Baseline measures

There were no group, time, or group×time effects for baseline RPE, $\dot{V}O_2$, heart rate, RQ, lactate, and MAP (table 2). Baseline fatigue was greater, and there was a trend for greater depression in the MS group, but fatigue and depression levels were consistent between weeks. Room temperature and humidity were not different between weeks; however, room temperature was lower in the MS group.

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Table 2. Preexercise baseline variables

Variables	Group	Week 1	Week 2	Main Effects, *P*		Interaction, *P*
$\dot{V}O_2$ (L/min)	MS	0.28±0.10	0.32±0.12	Group	.99	
	Non-MS	0.30±0.08	0.31±0.08	Time	.16	.33
$\dot{V}O_2$ (mL/kg/min)	MS	3.9±0.9	4.5±1.6	Group	.83	
	Non-MS	4.0±0.9	4.2±1.2	Time	.14	.37
HR (beats/min)	MS	69.1±15.0	73.3±15.1	Group	.38	
	Non-MS	74.7±12.0	76.5±6.5	Time	.10	.48
MAP (mmHg)	MS	90.1±7.5	90.3±8.3	Group	.88	
	Non-MS	89.9±8.0	89.6±6.3	Time	.97	.88
RQ	MS	0.84±0.09	0.82±0.12	Group	.95	
	Non-MS	0.83±0.06	0.82±0.14	Time	.50	.68
Lactate (mmol/L)	MS	2.9±2.6	1.9±0.5	Group	.65	
	Non-MS	2.1±0.8	2.2±1.1	Time	.24	.21
CES-D	MS	7.7±10.0	8.5±10.0	Group	.06*	
	Non-MS	2.1±2.0	2.7±3.0	Time	.49	.94
MFIS	MS	29.2±22.9	29.1±22.6	Group	<.001†	
	Non-MS	4.2±6.3	3.9±5.2	Time	.86	.95
Room temperature (°C)	MS	21.7±1.0	22.0±1.1	Group	.03†	
	Non-MS	22.9±1.9	22.9±1.8	Time	.37	.55
Room humidity (%)	MS	36.8±11.5	33.4±11.6	Group	.06	
	Non-MS	43.7±12.1	43.9±10.1	Time	.15	.11

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviations: CESD, Center for Epidemiologic Studies Depression Scale; HR, heart rate; MFIS, Modified Fatigue Impact Scale.
*Trend for significance.
†*P*<.05.

Submaximal test

The Young Men's Christian Association test produced similar predicted maximal workload, $\dot{V}O_2$, and heart rate in the MS and non-MS groups (table 3). The lack of difference between groups highlights that the MS group was only mildly to moderately impaired.

Table 3. Predicted maximal levels

Variables	MS Group	Non-MS Group	95% CI	*P*
$\dot{V}O_2$ (mL/kg/min)	37.4±13.5	35.4±10.3	−7.9 to 11.9	.684
Workload	178.4±84.3	184.4±62.4	−67 to 56	.844
HR (beats/min)	174.3±4.91	177.1±7.5	−7.7 to 2.1	.254

NOTE. Values are mean ± SD or as otherwise indicated.
Abbreviations: CI, confidence interval; HR, heart rate.

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Exercise measurements

Repeated-measures analysis of variance indicated no group (MS group vs non-MS group), time (week 1 vs week 2), or group×time effects for RPE, workload, $\dot{V}O_2$, or MAP (fig 1). Heart rate decreased from week 1 to week 2 (*P*=.015), but decreased similarly in both groups. RQ increased in both groups from week 1 to week 2 (*P*<.001), with a greater increase in the MS group (*P*=.008). All participants remained within the prescribed target training range based on the RPE during week 2 (reproduction protocol). Exercise physiological variables were similar among different MS disease types (data not shown, *P*>.05).

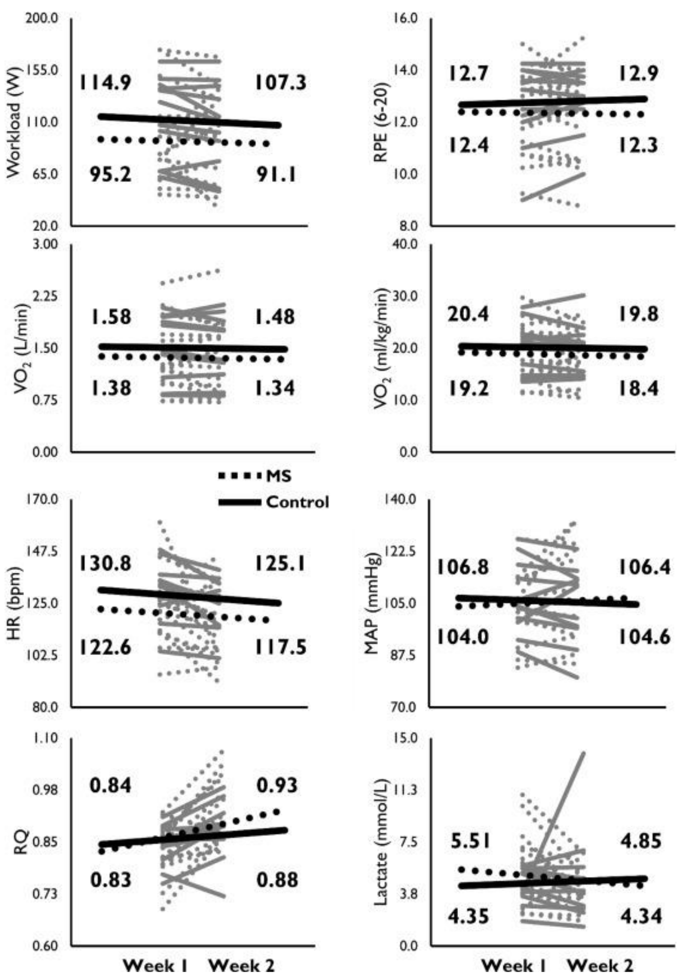

Fig 1. Responses to a prescribed RPE training range. Gray lines indicate individual data, whereas black lines represent group averages. Values displayed in the figure are average values for the indicated group. Abbreviation: HR, heart rate.

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RPE reliability

Table 4 indicates moderate to high reliability for key exercise variables for both MS and non-MS groups. Heart rate showed moderate reliability in both groups. In contrast, reliability for RQ and lactate were comparatively weak for both groups. Bland-Altman plots (fig 2) do not reveal any systematic biases. For RPE and other physiological measures, the average difference value is near 0, indicating reliable and agreeable measurements.

Table 4. ICCs between weeks 1 and 2

Variables	ICC	95% CI	*P*
MS group			
RPE	.870	.668 to .953	<.001*
Workload (W)	.862	.650 to .949	<.001*
$\dot{V}O_2$ (L/min)	.925	.799 to .973	<.001*
$\dot{V}O_2$ (mL/kg/min)	.850	.623 to .945	<.001*
HR (bpm)	.716	.357 to .891	.001*
RQ	.555	.100 to .818	.010*
Lactate (mmol/L)	.521	.052 to .802	.016*
MAP (mmHg)	.842	.577 to .946	<.001*
Non-MS group			
RPE	.938	.788 to .983	<.001*
Workload (W)	.962	.865 to .990	<.001*
$\dot{V}O_2$ (L/min)	.970	.894 to .992	<.001*
$\dot{V}O_2$ (mL/kg/min)	.954	.839 to .987	<.001*
HR (bpm)	.827	.481 to .950	<.001*
RQ	.754	.314 to .927	.001*
Lactate (mmol/L)	.205	−.421 to .699	.261
MAP (mmHg)	.871	.592 to .964	<.001*

Abbreviations: bpm, beats per minute; CI, confidence interval; HR, heart rate; ICC, intraclass correlation coefficient.
* $P<.05$.

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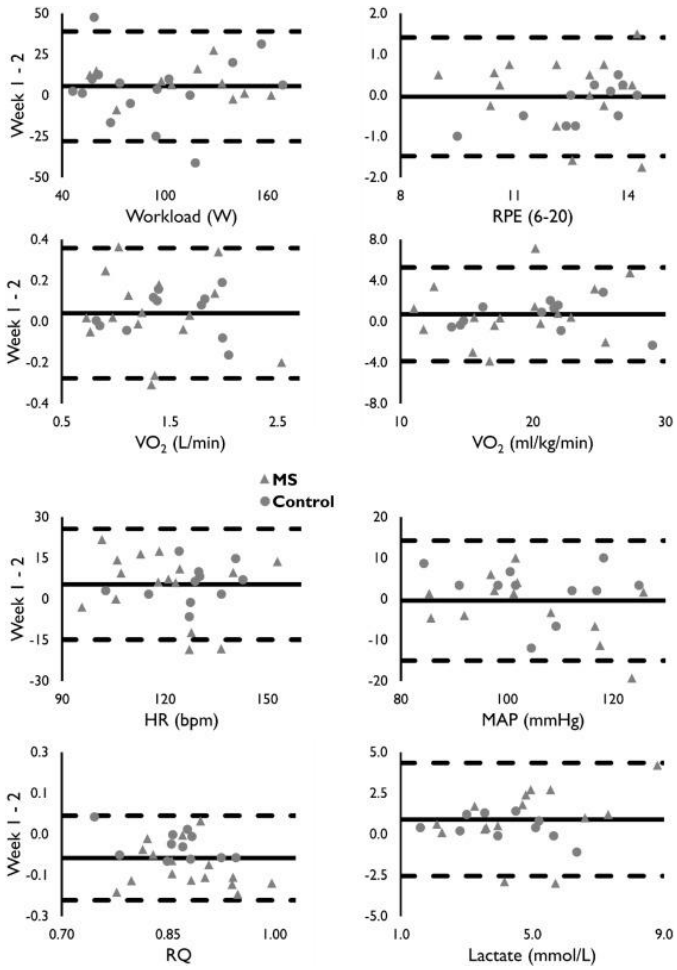

Fig 2. Bland-Altman plots of differences in RPE and exercise responses between week 1 and week 2. The solid dashed line represents the average difference value, whereas the top and bottom dashed lines represent 2 SD above and below the mean difference value, respectively. Triangles represent individual participants with MS, and the circles represent participants without MS. Abbreviation: HR, heart rate.

Convergent validity

Table 5 demonstrates that high correlations (convergent validity) were found between the RPE and workload and $\dot{V}o_2$ for both the MS and non-MS groups (criterion validity). In the non-MS group, the RPE also showed high correlations with RQ and MAP.

Table 5. Pearson correlations between physiological variables and RPE

Variables	Correlation With RPE		
	Week 1	Week 2	Average Estimate
MS group			
Workload (W)	.720*	.674*	.700
$\dot{V}O_2$ (L/min)	.723*	.660*	.691
$\dot{V}O_2$ (mL/kg/min)	.476	.536*	.507
HR (bpm)	−.336	−.225	−.282
RQ	.069	−.048	.019
Lactate (mmol/L)	−.476	.174	−.168
MAP (mmHg)	.121	.303	.211
Non-MS group			
Workload (W)	.596	.558	.581
$\dot{V}O_2$ (L/min)	.642*	.575	.613
$\dot{V}O_2$ (mL/kg/min)	.608*	.506	.566
HR (bpm)	−.379	−.058	−.219
RQ	.405	.562	.476
Lactate (mmol/L)	.235	−.012	.114
MAP (mmHg)	.789*	.627*	.717

Abbreviations: bpm, beats per minute; HR, heart rate.
$*P<.05$ for within-week correlations.

Discussion

To our knowledge, this study demonstrates for the first time that the Borg RPE scale (ratings 6–20) is reliable over 1 week in persons with mild to moderate MS during submaximal cycling exercise. RPE, workload, $\dot{V}O_2$, and MAP were all similar between weeks 1 and 2. Furthermore, these variables all had high intraclass correlations, suggesting that individual participants had similar RPEs (and other physiological measures) between weeks. Taken together, this suggests that key indicators of exercise intensity, including the RPE, were reproducible across 1 week.

This study also provides additional insight into the construct validity of the RPE in PwMS. The high positive correlations in PwMS between the RPE, $\dot{V}O_2$, and workload are what would be expected if the RPE was linear and perceptually mediated by $\dot{V}O_2$ and workload, as in persons without MS.[34] That heart rate correlated poorly with the RPE is consistent with heart rate being a mediating but not primary factor in determining the perceptual response to effort.[24] Blood lactate also

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poorly correlated with the RPE, but it is not thought to be linear with the RPE until concentrations are above the lactate threshold. The low mean RPE suggests that lactate concentrations were below this threshold.[24] The low correlation between the RPE and MAP in the MS group may reflect issues with cardiovascular autonomic control[17, 18, 19, 20 and 24] and confirms that MAP is not a primary mediator of the RPE.[24] Finally, PwMS may have had saturated RQ values, resulting in a low correlation with the RPE.

This study extends the findings of Morrison et al,[33] which demonstrated that the RPE is similar between persons with mild MS and people without MS during incremental cycling exercise. A similar result has been shown during sustained submaximal isometric contractions.[34] In contrast, Thickbroom et al[26] showed an exaggerated RPE in PwMS during isometric exercise compared with a non-MS group. Our findings may differ because Thickbroom had participants perform intermittent isometric contractions with a hand muscle, whereas our study used a lower-limb cycling protocol.[26] In this previous study, PwMS had a faster rate of increase in the RPE, but experienced similar relative muscle fatigue as people without MS. Therefore, PwMS may be less accurate when estimating exertion for a small muscle group. Overall, the literature appears to support the validity of the RPE in PwMS, at least during cycling exercise. By demonstrating reliability and further contributing to the validity of the RPE, we provide credible evidence for recommendations to use the RPE to monitor exercise intensity during aerobic exercise in PwMS.[1, 22 and 23]

Caution has been advised in using heart rate for exercise prescription in PwMS because potential cardiovascular autonomic impairment may lead to a blunted cardiovascular response[46 and 47]; however, this is controversial.[34] Our results do not necessarily support this concern because heart rate–based measures, including response to exercise, were similar in MS and non-MS groups. However, our results do not preclude individual altered cardiovascular regulation in PwMS as has been reported,[17, 18, 19, 20, 34 and 48] and individual assessment should take precedence in any exercise setting.

A submaximal exercise test was used as an initial method to determine exercise intensities and simulate an exercise prescription that might be encountered in a community health, fitness, or wellness

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setting.[15 and 16] Although submaximal exercise tests have limitations, the primary aim of this study was to determine whether a prescribed exercise response associated with a RPE is reproducible and valid based on the RPE. All measured values were within recommended levels for exercise in PwMS, including the RPE (12.5).[15 and 23]

Fatigue, depression, and disease status were stable across test sessions. Therefore, the validity of the RPEs in PwMS during a relapse or otherwise nonstable phase of disease cannot be determined from this study. One potential advantage of using the RPE to monitor exercise intensity in a symptom-limited population is that the RPE is independent of absolute work level and can be adjusted relative to physiological state (eg, disease, sickness, environment). For example, under symptom exacerbation, the absolute exercise workload may be appropriately lower at a similar target RPE. It is important that the use of the RPE under nonstable conditions be described systematically in future studies.

Study limitations

The small number of participants in our study suggests that our results should be considered of a pilot nature and interpreted with care. As discussed, some have suggested that caution must be taken when using submaximal data for predicting maximal $\dot{V}O_2$.[46] Therefore, a limitation is that we did not perform maximal $\dot{V}O_2$ tests; however, predicted values were consistent with what others have observed.[46] More importantly, the actual $\dot{V}O_2$ for the 2 exercise sessions was reproducible and similar between groups. The room temperature for PwMS was lower compared with people without MS. This difference in temperature likely did not affect the reliability of the RPE because temperature was similar between weeks for each group. All PwMS tested were ambulatory and mildly to moderately impaired. Consequently, our results should not be extrapolated to those who are more seriously impaired. Finally, we do not know if our results can be extrapolated to different exercise intensities, durations, or modes.

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Conclusions

These preliminary findings indicate that the Borg scale (ratings 6–20) can be reproducible over a week and are valid in persons with mild to moderate MS. Therefore, the RPE may be a reliable and valid method of monitoring and prescribing exercise intensity in PwMS during cycling exercise. Exercise recommendations in an MS population must be based on individual responses. Further investigation is needed in this important area of exercise prescription in PwMS.

Suppliers

a. BD.
b. Polar T31; Polar Electro.
c. Lactate Pro; Arkray.
d. SPSS Statistics 22.0; IBM.

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